Course Syllabus

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ASTRON 0113/0413: INTRODUCTION TO ASTROPHYSICS

Term: Spring 2025

Credits: 3

Prerequisites: MATH 0020 or any MATH greater than or equal to MATH 0031 (Min Grade: C) or MATH PLACEMENT SCORE (61 or greater)

Meeting Time: Tuesdays and Thursdays, 9:00-10:15 AM, 104 Thaw Hall

Honors section (ASTRON 0413): 4 credits, same meeting times (Tuesday/Thursday 09:00-10:15 AM), plus 12:00-12:50 PM on Tuesdays, 104 Allen Hall

Prerequisites for honors section: MATH 0230 or 0235, and PHYS 0110 or 0174 or 0475.

Instructor: Prof. Rachel Bezanson

Contact information

Email: rachel.bezanson@pitt.edu (email or Canvas are the best way to get in touch with me!)

Office: 311 Allen Hall (around the corner from the primary Allen hallway)

Office hours: Tuesday 10:30 - 11:30 am and Friday 2:00 - 3:00 pm

Course Description:

This course is an introduction to astronomy and astrophysics at the beginning undergraduate level, intended for students that are majoring in science or engineering. Broad familiarity with basic physical concepts such as force, energy, momentum, and temperature will be assumed, as well as college level mathematics. Algebra, geometry, and trigonometry will be used extensively throughout the course and will be needed to complete the homework sets and exams. Familiarity with calculus will be very helpful, but it is not required for ASTRON 0113 and will not be needed to complete any assignments in this course outside of the honors section.

This is a self-contained course focusing on astronomical objects that lie beyond the solar system and the nature of the Universe as a whole. The main topics are: *the properties and life-cycle of stars* including their birth, death and the formation of remnants such as black holes and neutron stars, *the nature and*

evolution of galaxies, including exotic objects such as quasars and starbursts, and *the origin and ultimate fate of the Universe* (cosmology).

Important note: If you are uncomfortable applying algebra and geometry, or you are not interested in studying astrophysical systems in detail, you may want to consider taking ASTRON 0087, 0088, or 0089, which are not designed for science majors and do not assume mathematical proficiency. Please contact me if you have any questions about your level of preparation.

Course Objectives:

This course has two primary objectives:

- To provide a basic knowledge of the Universe outside the Solar System, sufficient to prepare students for more advanced astronomy courses.
- To help students gain skills in solving scientific problems, including the use of approximation techniques and other methods of obtaining rough solutions.

Modern astronomy has become a vast field of study encompassing atomic and molecular physics, planetary science, the study of galactic structure, and much more. It would be impossible even to survey the subjects that most practicing astronomers would consider “basic knowledge” in a single semester. Therefore, some choices have to be made. This semester, ASTRON 0113 will cover the following areas: (1) basic problem solving using approximation techniques; (2) the law of gravity, the process that lead to our contemporary understanding of gravity, and its application to physical problems; (3) the fundamental properties of light, and their importance in astronomy (4) basic stellar physics and stellar classification; (5) the structure of galaxies; and (6) the evolution of our entire Universe (cosmology). The solar system is probably the astronomical system most familiar to beginning students and I will address the solar system only briefly in the first part of the course. This is a course designed for students who plan to continue in the sciences, and the emphasis will be on scientific thinking and problem solving. If there is a particular subject related to astronomical science that you find interesting, please let me know and I will try to cover it as part of the course if there is sufficient interest. My intention is to make this course as fun and productive as possible.

At the end of the course, you should be able to explain, among other things:

- how we can measure the properties of distant stars and galaxies using observations from the Earth and space
- why the Sun shines, and why it will not do so forever
- how most chemical elements are synthesized in stellar cores through nuclear fusion
- how the Sun and other stars form and die
- how the Milky Way Galaxy we live in is similar to (or different from) other galaxies

- why we believe many galaxies have black holes at their center
- what the main constituents of the Universe are, how it began, and what its ultimate fate will be

Textbook

This course is more detailed than the standard introductory surveys of astronomy for non-science majors such as ASTRON 0087, 0088, or 0089, yet not so advanced that sophisticated mathematical tools (such as calculus) can be brought to bear on astronomical problems. Unfortunately, there is no textbook available that is particularly appropriate for this level. A good option is the **openstax Astronomy book (https://openstax.org/details/books/astronomy)** by Fraknoi, Morrison, and Wolff, which can be downloaded electronically for free; therefore this is the resource that I recommend you draw upon for conceptual content, however the mathematical level is significantly below that of ASTRON 0113 in most cases. *21st Century Astronomy* by Kay, Palen, and Blumenthal (the Stars and Galaxies edition is sufficient) is another very good introductory book that makes only limited use of mathematics and has many excellent illustrations for students who prefer to have a physical reference, but we will cover most topics in more detail than is given in this book. *Astrophysics in a Nutshell* by Maoz is a great book. It provides an excellent introduction to most of the topics we will cover in this course including Light, Stellar Physics, Galaxies, and Cosmology. However, this book makes heavy use of calculus and therefore is a bit too advanced for ASTRON 0113. Other good textbooks include *Universe* by Freedman and Kaufmann (some math) and *Foundations of Astrophysics* by Ryden and Peterson and (more math, including calculus). Homework problems will not be taken from any specific textbook and no specific textbook will be necessary to complete this course. I will highlight the relevant chapter(s) in openstax Astronomy throughout the syllabus, but I recommend *Astrophysics in a Nutshell* for the more mathematically-inclined (and ASTRON 0413) students.

As there is no textbook for the course, taking good notes during lectures will be of critical importance. If you miss a class, I highly encourage you to consult a peer to obtain notes. I will post slides from all the lectures on Canvas after each class. Please check Canvas often for updates, and let me know if you have any problems downloading the files.

Goals

My main goal is to work with you to make this course engaging, interesting, and fun. Do not hesitate to contact me with *any* questions or concerns, either by email, Canvas, or dropping by office hours. I need your feedback in order to improve your learning experience! Please let me know if you have issues with the course material, or you would like me to cover some topic that you are particularly interested in. I may not be able to accommodate all requests, but I will certainly try.

Logistics

I will hold regular office hours on **Tuesdays from 10:30-11:30 AM and Fridays from 2:00 to 3:00 PM** (these times may occasionally change during the semester, but will always be up to date on Canvas and in this syllabus and any changes will be announced in class). If you cannot make these times,

please contact me and we can arrange to meet at another time. I highly encourage you to use me as a resource; the problem sets in this course can be challenging and I want to help you work through them! I will give 2 points of extra credit on the first homework assignment if you come to my office hours within the first two weeks of class and introduce yourself. If you need further help or would prefer to seek help from a tutor, the Department of Physics and Astronomy maintains a Physics Resource Room in 312 Thaw Hall that is staffed by tutors between 9 AM and 5 PM on weekdays throughout the semester. Please take advantage of this service.

Grading Policy

There will be 9 homework sets due throughout the course of the semester as well as a final project that will be due on Dec. 12. A full **50% of your grade will be based on your performance on the homework sets**. The reason for this emphasis on homework sets is to hone your problem solving skills in an environment that mimics what practicing scientists do, where you have ample time and resources to accomplish a given task. If you want to get a high grade in this course, I advise you to set aside enough time to work on the homework assignments - you will need it. I understand that some weeks are busier than others and will drop your lowest homework score (on an individual homework assignment) from your overall grade calculation. One benefit of this approach is that it will be difficult to do very poorly in this class if you do a good job on the homework assignments. **The final project will comprise another 30% of your grade**, split into four pieces that will be graded separately - a project proposal (2%), a project draft (4%), a presentation (4%), and the final project itself (20%). **The remaining 20% of your grade will consist of participation** as demonstrated by lecture quizzes, in-class activities, etc. If you are unable to attend a lecture for any reason, you will still be expected to complete any assigned lecture activities (which will be available through Canvas). **There will be no exams in this class.**

Additional Opportunities for Credit: Faculty, students, and postdocs at the University of Pittsburgh are actively involved in ongoing astrophysics research. We have regular research seminars that students are welcome to attend. From time to time you will have the opportunity to attend an astronomy-related presentation and submit a summary of that talk for extra credit (these are optional and will be counted in your homework grade average). I will discuss possible events during class and will post relevant links on Canvas. If you find an event that you would like to suggest, please let me know!

In all assignments, the focus will be on showing the correct reasoning. **NO CREDIT** will be given for a correct answer without the reasoning being clearly explained. A great deal of the credit for a problem may be given if the reasoning is correct, but the numerical answer is incorrect for one reason or another. To get full credit for a problem, you *must* give a complete explanation of your reasoning. Occasionally, you may find an answer that is obviously incorrect. For example, say you derived the distance to the Sun to be three miles. In such a situation, you can still get partial credit for the problem simply by recognizing that the answer obviously does not make sense and explaining why the answer is manifestly incorrect. Finally, your work must be legible. **NO CREDIT** will be given for work that I or the TA find illegible. **NO CREDIT** will be given if I find it difficult to follow the sequence of steps. Your work must flow sequentially from left to right across the page and from the top to the bottom of the page. It is your responsibility, and

yours alone, to make sure that your work is legible and orderly. You may discuss problems with others on your homework sets, but the solutions you hand in must be your original work. **Using online services like Chegg to look up homework problems is cheating!** If I discover that you have copied a solution, **NO CREDIT** will be given for that assignment. Homework should be turned in by the beginning of class on the day that assignments are due. Late homework will be accepted with the grade reduced by 10% per 24 hours.

Attendance

Attendance in this class will not be mandatory and absences will not impact your grade. However, if you miss a class, you are responsible for obtaining notes and completing all associated in-class participation assignments. If you are unable to attend classes for a period of a week or more, please email me directly so that we can discuss your situation.

The Department of Physics & Astronomy

As students at the University of Pittsburgh, you have access to a Physics and Astronomy Department that is widely recognized and is performing world-class research. We in the Department of Physics and Astronomy want you to feel welcome. If you are interested in further study of or research in physics or astronomy please talk to me or any other faculty member.

The Department of Physics and Astronomy provides free assistance for all students. The Physics Exploration Center allows students to operate some simple experiments and demonstrations. Within the Exploration Center is the Physics Resource Room, staffed with TAs who can answer homework related questions, explain basic concepts and help you with the math. This is a free service and you are encouraged to use it. Both the Exploration Center and the Resource Room are located in Thaw 312, and a detailed schedule is posted here: **https://www.physicsandastronomy.pitt.edu/resource-room-information (https://www.physicsandastronomy.pitt.edu/resource-room-information)** . In addition, tutoring is available through the Academic Support Center (WPU 311). You may also make use of the undergraduate lounge off of the mail room on the second floor of the Old Engineering Hall. This is a good place to meet with classmates to discuss problem sets and course material. You might also meet physics and astronomy majors here that can help you, discuss other classes with you, or inform you about the major program. The Department hosts a donut and coffee hour every Wednesday at 4PM, which is designed to encourage discussion. The Astrophysics group within the Department hosts seminars on topics of current interest in astronomy and astrophysics every other Friday at 11am. The talks are typically at an advanced level, but eager students can learn a great deal about contemporary astronomy and astrophysics by attending (and can obtain credit for doing so). You can find the talk schedule on the Department web site: http://www.physicsandastronomy.pitt.edu.

Academic Integrity

The integrity of the academic process requires fair and impartial evaluation on the part of faculty and honest academic conduct on the part of students. To this end, students are expected to conduct themselves at a high level of responsibility in the fulfillment of their course of study. It is the corresponding responsibility of faculty to make clear to students those standards by which students will be evaluated and the resources permissible for use by students during the course of their study and evaluation. The educational process is perceived as a joint faculty-student enterprise which will perforce involve professional judgment by faculty and may involve - without penalty - reasoned exception by students to the data or views offered by faculty.

Cheating/plagiarism will not be tolerated. Students suspected of violating the University of Pittsburgh Policy on Academic Integrity, from the February 1974 Senate Committee on Tenure and Academic Freedom reported to the Senate Council, will be required to participate in the outlined procedural process as initiated by the instructor. A minimum sanction of a zero score for the quiz or exam will be imposed. For details, refer to the **University Guidelines on Academic Integrity (https://www.provost.pitt.edu/sites/default/files/academic_integrity_guidelines.pdf)** .

Diversity and Inclusion

I consider this class to be a place where you will be treated with respect, and I welcome individuals of all ages, backgrounds, beliefs, ethnicities, genders, gender identities, gender expressions, national origins, religious affiliations, sexual orientations, ability - and other visible and non-visible differences. All members of this class are expected to contribute to a respectful, welcoming and inclusive environment for every other member of the class.

Disabilities

If you require special accommodations or classroom modifications, please notify both your instructor and Disability Resources and Services by the end of the first week of the term. The office of Disability Resources and services is located in 140 William Pitt Union, (412) 648-7890, drsrecep@pitt.edu, (412-228-5347 [voice or TDD]), and their website is at **http://www.drs.pitt.edu (http://www.drs.pitt.edu)** . If you have a physical, learning, or emotional disability, please let me know as early as you can so that appropriate accommodations can be made.

Syllabus Addendum: Natural Science General Education Requirement

This course fulfills one Dietrich School of Arts and Sciences Natural Science General Education Requirement (GER) as described for the GERs starting Fall 2018 (term 2191). That GER reads as follows: Three Courses in the Natural Sciences: These will be courses that introduce students to scientific principles and concepts rather than offering a simple codification of facts in a discipline or a history of a discipline. The courses may be interdisciplinary, and no more than two courses may have the same primary departmental sponsor.

Schedule

Below is a tentative schedule of topics covered in ASTRON 0113, which may be modified according to student interests and pacing as the semester progresses.

(1) **Jan 9**: Introductory Material; Astronomy as a Science; Order of Magnitude

(2) **Jan 14**: The Science of Astronomy and Steps Towards the Theory of Gravity

(3) **Jan 16**: Newton's Laws and the Universal Law of Gravitation; **Pset 1 due (order of magnitude calculations, basic trig etc)**

(4) **Jan 21**: Energy and Gravitation

Add/Drop period ends January 21

(5) **Jan 23**: Conservation Laws and Spaceflight; **Pset 2 due (basic orbits, Kepler's Laws)**

(6) **Jan 28**: Angular Momentum, Introduction to Light

(7) **Jan 30**: Emission, Absorption, Doppler Effect, Blackbody Radiation; **Pset 3 due (Newton's gravity, Tides etc)**

(8) **Feb 4**: Telescopes and Basic Optics

(9) **Feb 6**: Intro to Stars

(10) **Feb 11**: Stars, the HR diagram, and hydrostatic equilibrium

(11) **Feb 13**: The Sun; **Pset 4 due (Light as particle/wave, Blackbody radiation)**

(12) **Feb 18**: The Interstellar Medium and Star Formation

(13) **Feb 20**: The Life & Times of a Low-Mass Star; **Pset 5 due (The Sun, HR Diagram)**

(14) **Feb 25**: Binary Stars, The Life & Times of a Massive Star

(15) **Feb 27**: Stellar Remnants, Black Holes, and Gravitational Waves; **Pset 6 due (The Sun, hydrostatic equilibrium, inverse square law)**

Spring Break

(16) **Mar 11**: Star Clusters and Stellar Populations

(17) **Mar 13**: A Historical Introduction to Galaxies in the Universe; **Pset 7 due (Stellar lifecycles, remnants etc.)**

(18) **Mar 18**: What Shapes Galaxies?

(19) **Mar 20**: Mysteries in Galaxies: AGN, Supermassive Black Holes, & Dark Matter

(20) **Mar 25**: The Milky Way Galaxy and its Structure

(21) **Mar 27**: Introduction to Cosmology; **Pset 8 due (Galaxies, Dark Matter)**

(22) **Apr 1**: The Expanding Universe and its Consequences

(23) **Apr 3**: The Major Predictions of the Big Bang and the Theory of Cosmic Evolution

(24) **Apr 8**: The Contemporary Universe: Evidence for Dark Matter and Dark Energy

(25) **Apr 10**: JWST and Astronomy in the News; **Pset 9 due (Expanding Universe and Cosmology)**

(26) **Apr 15**: Final Project Presentations; **Final Project Draft due**

(27) **Apr 18:** Final Project Presentations

(28) **Apr 22:** Final Project Presentations

Apr 24: Final Project due